NATIONAL ENGINEERING HANDBOOK

SECTION 4

HYDROLOGY

CHAPTER 9. HYDROLOGIC SOIL-COVER COMPLEXES

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SECTION 4

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CHAPTER 9--HYDROLOGIC SOIL-COVER COMPLEXES

CONTENTS

CHAPTER 9. HYDROLOGIC SOIL-COVER COMPLEXES

A combination of a hydrologic soil group (soil) and a land use and treatment class (cover) is a hydrologic soil-cover complex. This chapter gives tables and graphs of runoff curve numbers (CN) assigned to such complexes. Its CN indicates the runoff potential of a complex during periods when the soil is not frozen, the higher a CN the higher a potential, and specifies which runoff curve of figure 10.1 is to be used in estimating runoff for the complex (chap. 10). Applications and further discussions of CN are given in chapters 10, 11, and 12.

Determinations of Complexes and CN

AGRICULTURAL LAND

Complexes and assigned CN for combinations of soil groups of chapter 7 and land use and treatment classes of chapter 8 are given in table 9.1. Also given are some complexes that make applications of the table more direct. Impervious and water surfaces, which are not listed, are always assigned a CN of 100.

ASSIGNMENT OF CN TO COMPLEXES. Table 9.1 was developed as follows. The data literature was searched for watersheds in single complexes (one soil group and one cover); watersheds were found for most of the listed complexes. An average CN for each watershed was obtained by the method of example 5.4, using rainfall-runoff data for storms producing the annual floods (chap. 18). The watersheds were generally less than 1 square mile in size, the number of watersheds for a complex varied, and the storms were of 1 day or less duration. The CN of watersheds in the same complex were averaged, all CN for a cover were plotted as shown in figure 7.2, a curve for each cover was drawn with greater weight given to CN based on data from more than one watershed, and each curve was extended as far as necessary to provide CN for ungaged complexes. All but the last three lines of

Table 9.1.--Runoff curve numbers for hydrologic soil-cover complexes

(Antecedent moisture condition II, and $I_a = 0.2\ S$)

Land use	Cover: Treatment or practice	Cover: Hydrologic condition	Hydrologic soil group: A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	"and terraced	Poor	66	74	80	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	"and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight row	Poor	66	77	85	89
	" "	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	"and terraced	Poor	63	73	80	83
	"and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt) 2/		----	72	82	87	89
(hard surface) 2/		---	74	84	90	92

1/ Close-drilled or broadcast.
2/ Including right-of-way.

Table 9.1A.--Runoff curve numbers for hydrologic soil-cover complexes for conservation tillage and residue management

(Antecedent moisture condition II, and $I_a = 0.2S$)

Land use	Cover Treatment or practice	Hydrologic condition 1/	Hydrologic soil group A	B	C	D
Fallow	Conservation tillage	poor	76	85	90	93
	Conservation tillage	good	74	83	88	90
Row crops	Conservation tillage	poor	71	80	87	90
	Conservation tillage	good	64	75	82	85
	Contoured + conservation tillage	poor	69	78	83	87
		good	64	74	81	85
	Contoured + terraces + conservation tillage	poor	65	73	79	81
		good	61	70	77	80
Small grain	Conservation tillage	poor	64	75	83	86
	Conservation tillage	good	60	72	80	84
	Contoured + conservation tillage	poor	62	73	81	84
		good	60	72	80	83
	Contoured + terraces + conservation tillage	poor	60	71	78	81
		good	58	69	77	80

1/ For conservation tillage poor hydrologic condition, 5 to 20 percent of the surface is covered with residue (less than 750 #/acre row crops or 300 #/acre small grain).

For conservation tillage good hydrologic condition, more than 20 percent of the surface is covered with residue (greater than 750 #/acre row crops or 300 #/acre small grain).

NOTE: Percent cover should be estimated at the time of year storms occur.

CN entries in table 9.1 are taken from these curves. For the arbitrary complexes in the last three lines the proportions of different covers were estimated and CN computed from previously derived CN.

Table 9.1 has not been significantly changed since its construction in 1954 but supplementary tables for special regions have been developed. These tables are given later in this chapter.

USE OF TABLE 9.1. Chapters 7 and 8 describe how soils and cover of a watershed or other land area are classified in the field. After the classification is completed, CN are read from table 9.1 and applied as described in chapter 10. Because the principal use of CN is for estimating runoff from rainfall, the examples of applications are given in chapter 10.

NATIONAL AND COMMERCIAL FOREST: FOREST-RANGE

Chapter 4 of "Forest and Range Hydrology Handbook," U.S. Forest Service, Washington, D. C., 1959, describes how CN are determined for national and commercial forests in the eastern United States. Section 1 of "Handbook on Methods of Hydrologic Analysis," U.S. Forest Service, Washington, D. C., 1959, describes how CN are determined for forest-range regions in the western United States. Selections from these handbooks are given here to show the differences from SCS procedure; the handbooks should be consulted for details and examples.

Forest in Eastern United States

In the humid forest regions of the eastern United States, soil group, humus type, and humus depth are the principal factors used in the Forest Service method of determining CN. The undecomposed leaves or needles, twigs, bark, and other vegetative debris on the forest floor form the litter from which humus is derived. Litter protects humus from oxidation and therefore indirectly enters into the determination; if the depth of litter is less than 1/2 inch the humus is considered unprotected and the hydrologic condition class (fig. 9.1) is reduced by 0.5.

Humus is the organic layer immediately below the litter layer from which it is derived. It may consist of mull, which is an intimate mixture of organic matter and mineral soil, or of mor, which is practically pure organic matter unrecognizable as to origin from material lying on the forest floor. Humus depth increases with age

of forest stand until an equilibrium is reached between the processes that build up humus and those that break it down. As much as 12 inches of humus may be produced under favorable conditions, but a depth of 5 or 6 inches is considered the maximum attainable under average conditions. Under good management practices (proper use, protection, and improvement), humus is porous and has high infiltration and storage capacities. Under poor management practices (burning, overcutting, or overgrazing), humus is compact enough to impede the absorption of water.

Humus is evaluated by means of degrees of compaction, which are:

1. Compact. Mulls are firm; mors are felty.

2. Moderately compact. A transition stage.

3. Loose or friable. Mulls are not firm; mors are not felty.

Frost in compact humus is the concrete form, which inhibits infiltration, and in loose humus it is the granular or stalactite form, which does not. Because of the correlation between humus type and frost, a separate determination of the effects of frost is unnecessary.

The hydrologic condition of a forest area is the runoff-producing potential. The condition class is indicated by a number ranging from 1 to 6, the lower the number the higher the potential. The relation between classes and humus type and depth is shown in figure 9.1.

DETERMINATION OF CN FOR PRESENT HYDROLOGIC CONDITION. The CN for the present hydrologic condition of a forest area is determined as follows: sample plots are located in the area; soil group, litter depth, humus type, and humus depth are determined by means of shallow soil wells dug in the plots; the nomograph, figure 9.1, gives the hydrologic condition class of the plot; the network chart, figure 9.2, gives the CN. An average or weighted CN is obtained as described in chapter 10.

DETERMINATION OF CN FOR FUTURE HYDROLOGIC CONDITION. The CN for the future hydrologic condition of a forest area is determined from the improvement potential of the area, which is estimated by means of table 9.2. Definitions of terms used in the table are:

Improvement potential. The potential for improvement of the hydrologic condition of a site by proper use and treatment in the future. Physiography of the site enters into the determination of potential. The symbols for classes of potential are H = high, M = moderate, and L = low. A high potential means the most rapid rate of improvement, a low potential the slowest.

Table 9.2.--Physiographic factors and forest hydrologic-condition-improvement potential indexes

Aspect	Soil class	Soil depth	Slope position											
			Lower slope (streambank to one-fourth distance up slope)			One-fourth to one-half distance up slope			One-half to three-fourths distance up slope			Upper slope (three-fourths distance to top of slope)		
			Slope percent			Slope percent			Slope percent			Slope percent		
			0-20	21-40	41+	0-20	21-40	41+	0-20	21-40	41+	0-20	21-40	41+
		(inches)												
North to east	Clay	13-24	H	H	M	H	M	M	M	M	L	M	L	L
		25+	H	H	H	H	H	H	H	H	M	H	M	M
	Loam	13-24	H	H	H	H	H	M	H	M	M	M	M	L
		25+	H	H	H	H	H	H	H	H	H	H	H	M
	Sand	13+	H	M	M	M	M	L	M	L	L	L	L	L
South to west	Clay	13-24	M	M	L	M	L	L	L	L	L	L	L	L
		25+	H	M	M	M	M	L	M	L	L	L	L	L
	Loam	13-24	H	M	M	M	M	L	M	L	L	L	L	L
		25+	H	H	H	H	H	M	M	M	M	M	M	L
	Sand	13+	M	L	L	L	L	L	L	L	L	L	L	L
Northwest and southwest	Clay	13-24	H	M	L	M	M	L	M	L	L	L	L	L
		25+	H	H	H	H	M	M	H	M	L	M	M	L
	Loam	13-24	H	H	M	H	M	M	M	M	L	M	L	L
		25+	H	H	H	H	H	H	H	H	M	H	M	M
	Sand	13+	M	L	L	M	L	L	L	L	L	L	L	L

This is table 4.1 in U.S. Forest Service "Forest and Range Hydrology Handbook."

Aspect. A compass reading to the nearest octant, taken from the center of the sample plot and looking downslope on a line at right angles to the contours.

Soil class. Texture of the mineral soil immediately below the humus layer if any. Note that these classes differ from the soil groups of chapter 7 because the classes are concerned with forest growth, the groups with runoff.

Soil depth. A determination made in the sample plot. Rock outcrops or soils less than 13 inches deep are put in the 13- to 24-inch class.

Slope. A percentage reading of land slope, taken at the center of the plot.

Slope position. A forest growth class based on the vertical position of the plot relative to a stream (fig. 9.3).

Once the improvement potential is known, the time period for achieving the potential is estimated on the basis of use and treatment to be given the area; consideration is given to measures for protection from fire, overgrazing, overcutting, damaging logging, and epidemics of insects or diseases, to tree planting in open fields or woods openings, and to stand improvement. The CN for the area is estimated using figure 9.4, as illustrated in the following example.

Example 9.1.--A forest area has a present hydrologic condition class of 1.3 and soils in the A group. The improvement potential is high and it is estimated that a 50-year period is necessary to bring the area to this level. Determine the future CN for the area.

1. Determine the present CN. Enter figure 9.2 with the hydrologic condition class of 1.3 and at the line for soil group A read a CN of 54.

2. Determine the future hydrologic condition class. Enter figure 9.4 with the present class of 1.3, go across to the curve for high potential, and read 6 years on the time scale. To this value add one-half the improvement period: 6 + (50/2) = 31 years, follow the "high" curve to its intersection with 31 years on the time scale, and read a future class of 3.4. This estimate is based on 100 percent accomplishment of recommended use and treatment; if less accomplishment is expected, the condition class is proportionately reduced.

3. Determine the future CN. Enter figure 9.2 with the future class of 3.4 and at the line for soil group A read a CN of 37.

Forest-Range in Western United States

In the forest-range regions of the western United States, soil group, cover type, and cover density are the principal factors used in estimating CN. Figures 9.5 and 9.6 show the relationships between these factors and CN for soil-cover complexes used to date. The figures are based on information in table 2.1, part 2, of the Forest Service "Handbook on Methods of Hydrologic Analysis." The covers are defined as follows:

Herbaceous.--Grass-weed-brush mixtures with brush the minor element.

Oak-Aspen.-- Mountain brush mixtures of oak, aspen, mountain mahogany, bitter brush, maple, and other brush.

Juniper-Grass.--Juniper or piñon with an understory of grass.

Sage-Grass.--Sage with an understory of grass.

The amount of litter is taken into account when estimating the density of cover.

Present hydrologic conditions are determined from existing surveys or by reconnaissance, and future conditions from the estimate of cover and density changes due to proper use and treatment.

SUPPLEMENTARY TABLES OF CN

Tables 9.3, 9.4, and 9.5 are supplements to table 9.1 and are used in the same way.

Table 9.3 gives CN for selected covers in Puerto Rico. The CN were obtained using a relation between storm and annual data and the annual rainfall-runoff data for experimental plots at Mayaguez.

Table 9.4 gives CN for complexes in a typical watershed in Contra Costa County, California. The CN were obtained by the Contra Costa County Flood Control District and SCS, using streamflow data from the watershed and a trial-and-error process. The range in CN for a particular cover and soil group indicates the variation for soil subgroups.

Table 9.5 gives CN for sugarcane complexes in Hawaii. The CN are tentative estimates now undergoing study. Degrees of cover in the table are defined as follows:

Table 9.3.--Runoff curve numbers for hydrologic soil-cover complexes in Puerto Rico (antecedent moisture condition II, and I_a = 0.2 S).

Cover and condition	Hydrologic soil group			
	A	B	C	D
Fallow	77	86	91	93
Grass (bunch grass, or poor stand of sod)	51	70	80	84
Coffee (no ground cover, no terraces)	48	68	79	83
Coffee (with ground cover and terraces)	22	52	68	75
Minor crops (garden or truck crops)	45	66	77	83
Tropical kudzu	19	50	67	74
Sugarcane (trash burned; straight-row)	43	65	77	82
Sugarcane (trash mulch; straight row)	45	66	77	83
Sugarcane (in holes; on contour)	24	53	69	76
Sugarcane (in furrows; on contour)	32	58	72	79

Table 9.4.--Runoff curve numbers for hydrologic soil-cover complexes of a typical watershed in Contra Costa County, California (antecedent moisture condition II, and I_a = 0.2 S).

Cover	Condition	Hydrologic soil group			
		A	B	C	D
Scrub (native brush)	----	25-30	41-46	57-63	66
Grass-oak (native oaks with understory of forbs and annual grasses)	Good	29-33	43-48	59-65	67
Irrigated pasture	Good	32-37	46-51	62-68	70
Orchard (winter period with understory of cover crop)	Good	37-41	50-55	64-69	71
Range (annual grass)	Fair	46-49	57-60	68-72	74
Small grain (contoured)	Good	61-64	69-71	76-80	81
Truck crops (straight-row)	Good	67-69	74-76	80-83	84
Urban areas:					
Low density (15 to 18 percent impervious surfaces)		69-71	75-78	82-84	86
Medium density (21 to 27 percent impervious surfaces)		71-73	77-80	84-86	88
High density (50 to 75 percent impervious surfaces)		73-75	79-82	86-88	90

Table 9.5.--Runoff curve numbers; tentative estimates for sugarcane hydrologic soil-cover complexes in Hawaii (antecedent moisture condition II, and $I_a = 0.2\ S$).

Cover and treatment	Hydrologic soil group			
	A	B	C	D
Sugarcane:				
Limited cover, straight row	67	78	85	89
Partial cover, straight row	49	69	79	84
Complete cover, straight row	39	61	74	80
Limited cover, contoured	65	75	82	86
Partial cover, contoured	25	59	75	83
Complete cover, contoured	6	35	70	79

Limited cover.--Cane newly planted, or ratooned cane with a limited root system; canopy over less than 1/2 the field area.

Partial cover.--Cane in the transition period between limited and complete cover; canopy over 1/2 to nearly the entire field area.

Complete cover.--Cane from the stage of growth when full canopy is provided to the stage at harvest.

Straight-row planting is up and down hill or cross-slope on slopes greater than 2 percent. Contoured planting is the usual contouring or cross-slope planting on slopes less than 2 percent.

* * * *

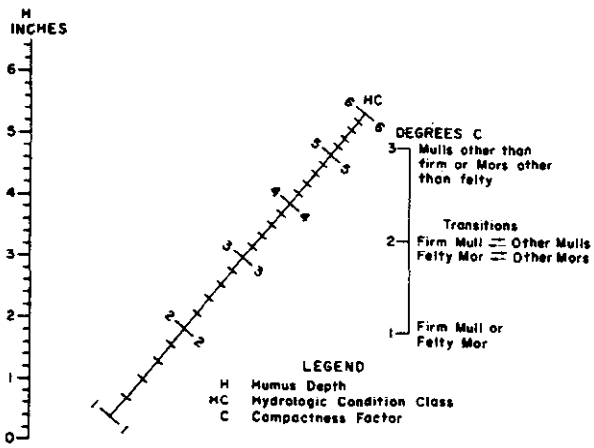


FIGURE 9.1 PRESENT HYDROLOGIC CONDITION OF FOREST AND WOODLAND

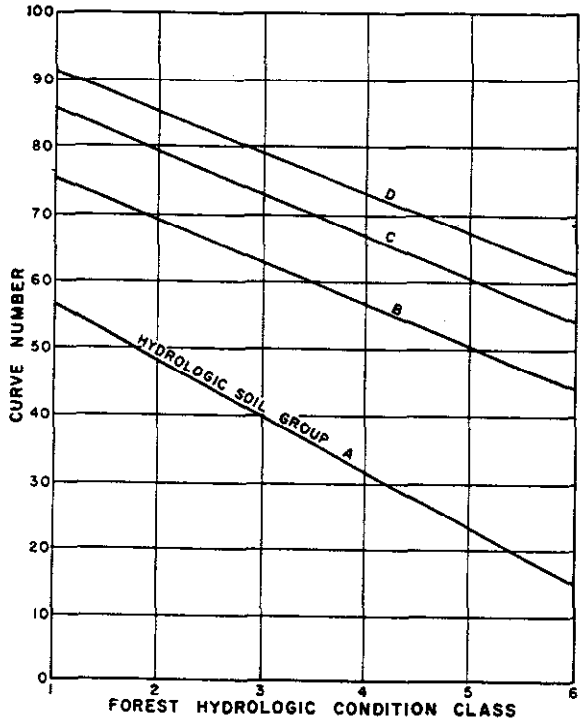
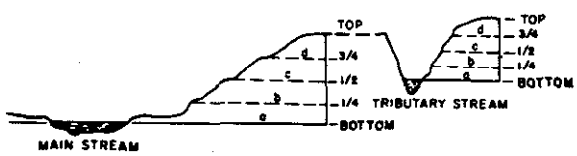
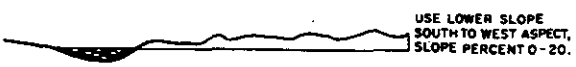


FIGURE 9.2 CURVE NUMBERS BY HYDROLOGIC SOIL GROUP AND FOREST HYDROLOGIC CONDITION CLASSES



A. - TRIBUTARY STREAM IN RELATION TO MAIN STREAM, MOUNTAINOUS

B. - PLATEAUS AND FOOTHILLS



C. - PRAIRIES, COASTAL PLAIN

a - LOWER SLOPE
b - 1/4 TO 1/2 DISTANCE UP SLOPE
c - 1/2 TO 3/4 DISTANCE UP SLOPE
d - UPPER SLOPE

FIGURE 9.3 - EXAMPLES OF SLOPE POSITION

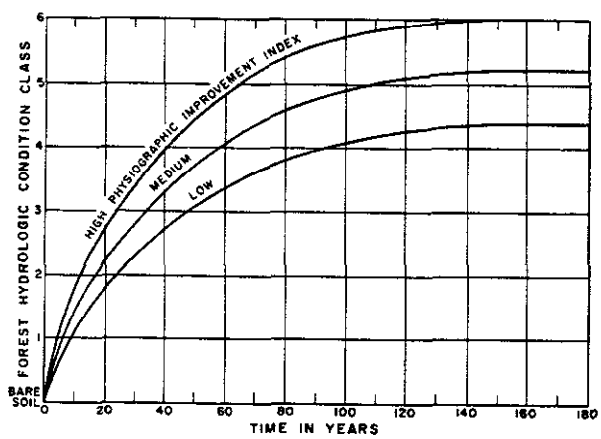


FIGURE 9.4 RATE OF IMPROVEMENT OF FOREST HYDROLOGIC CONDITION UNDER MANAGEMENT. STARTING CONDITION - BARE SOIL

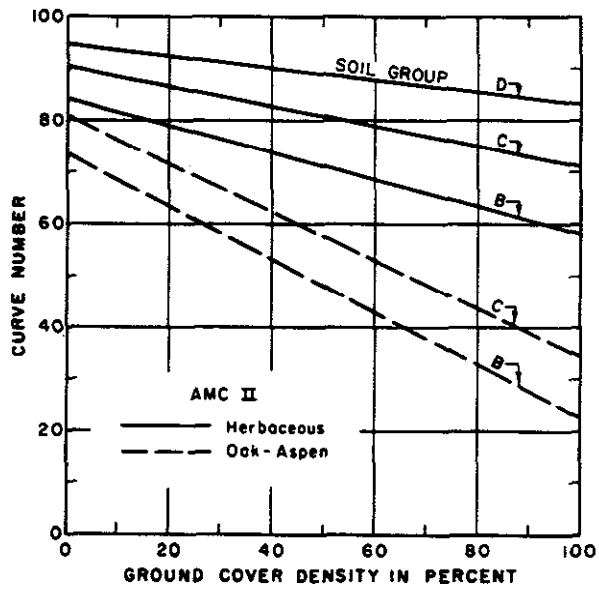


Figure 9.5.--Graph for estimating runoff curve numbers of forest-range complexes in western United States: herbaceous and oak-aspen complexes.

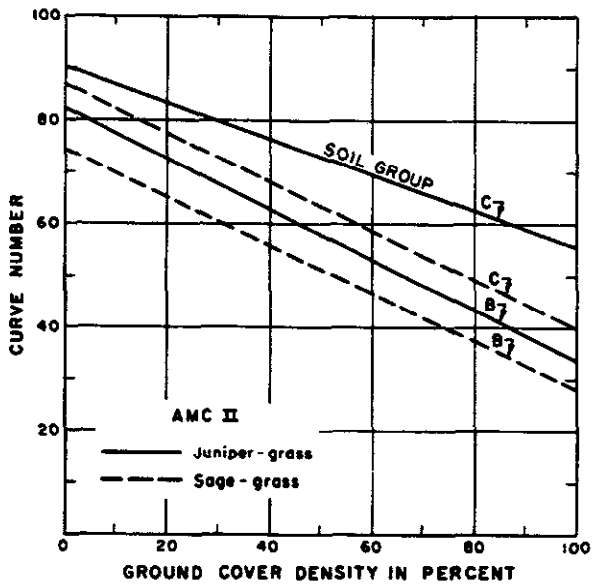


Figure 9.6.--Graph for estimating runoff curve numbers of forest-range complexes in western United States: juniper-grass and sage-grass complexes.